Sonic Thermometer for High-Altitude Balloons

A stand-alone version of the sensor would have utility as a gas composition sensor in industrial process situations.

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The sonic thermometer is a specialized application of well-known sonic anemometer technology. Adaptations have been made to the circuit, including the addition of supporting sensors, which enable its use in the high-altitude environment and in non-air gas mixtures.

There is a need to measure gas temperatures inside and outside of superpressure balloons that are flown at high altitudes. These measurements will allow the performance of the balloon to be modeled more accurately, leading to better flight performance. Small thermistors (solid-state temperature sensors) have been used for this general purpose, and for temperature measurements on radiosondes. A disadvantage to thermistors and other physical (as distinct from sonic) temperature sensors is that they are subject to solar heating errors when they are exposed to the Sun, and this leads to issues with their use in a very high-altitude environment.

While sonic anemometers and thermometers are commonly encountered in surface-based applications, they are not found in a high-altitude [e.g., 100,000 ft (≈30.5 km) and above] environment. One reason for this is the very thin air and correspondingly poor sound propagation encountered at these altitudes. A second issue is that the gas temperature inside the balloon is required. Aside from mounting considerations, this also leads to a need to operate correctly in a helium or helium/air gas mixture. The gas composition must be known via some means in order to compute accurate temperatures.

To make accurate sonic temperature measurements, the mean molecular weight of the gas the sensor is working in must be known, as must the value for gamma (the ratio of gas heat capacity at constant pressure divided by gas heat capacity at constant volume) for that gas. Therefore, a supporting measurement is required that directly or indirectly allows gas composition and gamma to be determined. With this data, the speed of sound as measured by the sonic thermometer can then be used to compute an accurate temperature.

The key addition to the basic sonic thermometer design was a sensor that, in this case, measured gas heat capacity at constant pressure. This data could then be used to identify the gas mixture composition (ranging from pure helium to pure air), and with that data both mean gas molecular weight and gamma could be computed. In turn, this data is required for the temperature calculation.

The supporting sensor used for gas composition/molecular weight/gamma measurement is built as an integral part of the sonic thermometer circuitry, and consists of a pair of simple semiconductor sensors. During measurements, a gas composition measurement is made at the same time as a speed of sound measurement is made by the sonic thermometer. Thus, each measurement has its own gas composition data associated with it, enabling a precise temperature computation to be completed.

This work was done by John Bognar of Anasphere for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16104-1

Near-Infrared Photon-Counting Camera for High-Sensitivity Observations

Extremely faint phenomena and NIR signals emitted from distant celestial objects can be observed and imaged.

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The dark current of a transferred-electron photocathode with an InGaAs absorber, responsive over the 0.9-to-1.7-μm range, must be reduced to an ultralow level suitable for low signal spectral astrophysical measurements by lowering the temperature of the sensor incorporating the cathode. However, photocathode quantum efficiency (QE) is known to reduce to zero at such low temperatures. Moreover, it has not been demonstrated that the target dark current can be reached at any temperature using existing photocathodes.

Changes in the transferred-electron photocathode epistructure (with an InGaAs absorber lattice-matched to InP and exhibiting responsivity over the 0.9-to-1.7-μm range) and fabrication processes were developed and implemented that resulted in a demonstrated >13× reduction in dark current at –40 °C while retaining >95% of the ≈25% saturated room-temperature QE. Further testing at lower temperature is needed to confirm a >25 °C predicted reduction in cooling required to achieve an ultralow dark-current target suitable for faint spectral astronomical observations that are not otherwise possible. This reduction in dark current makes it possible to increase the integration time of the imaging sensor, thus enabling a much higher near-infrared (NIR) sensitivity than is possible with current technology. As a result, extremely faint phenomena and NIR signals emitted from distant celestial objects can be now observed and imaged (such as the dynamics of redshifting galaxies, and spectral measurements on extra-solar planets in search of water and bio-markers) that were not previously possible. In addition, the enhanced NIR sensitivity also directly benefits other NIR imaging applications, including drug and bomb detection, stand-off detection of improvised explosive devices (IED's), Raman spectroscopy and microscopy for life/physical science applications, and semiconductor product defect detection.